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A close encounter of the massive kind

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ABSTRACT

We have used (i) *Hubble Space Telescope* Advanced Camera for Surveys imaging and Space Telescope Imaging Spectrograph spectroscopy, (ii) ground-based Precision Integrated-Optics Near-infrared Imaging ExpeRiment/Very Large Telescope long-baseline interferometry, and (iii) ground-based spectroscopy from different instruments to study the orbit of the extreme multiple system HD 93 129 Aa,Ab, which is composed of (at least) two very massive stars in a long-period orbit with $e > 0.92$, which will pass through periastron in 2017/2018. In several ways, the system is an η Car precursor. Around the time of periastron passage, the two very strong winds will collide and generate an outburst of non-thermal hard X-ray emission without precedent in an O+O binary since astronomers have been able to observe above Earth's atmosphere. A coordinated multiwavelength monitoring in the next two years will enable a breakthrough understanding of the wind interactions in such extreme close encounters. Furthermore, we have found evidence that HD 93 129 Aa may be a binary system itself. In that case, we could witness a three-body interaction which may yield a runaway star or a stellar collision close to or shortly after the periastron passage. Either of those outcomes would be unprecedented, as they are predicted to be low-frequency events in the Milky Way.

Key words: ephemerides – binaries: visual – stars: individual: HD 93 129 Aa,Ab – stars: kinematics and dynamics – stars: winds, outflows – X-rays: stars.

1 INTRODUCTION

Massive stars love company, with the vast majority of them (if not all) being born in multiple systems of two or more stars (Mason et al. 1998; Sana et al. 2012, 2014; Sota et al. 2014). Many of those systems are in low-eccentricity, short-period (1 d to a few months) orbits which lead to slow, prolonged interactions which play an important role in their evolution (Pols 1994). Recent studies have discovered a population of eccentric systems with periods around 1 year (Maíz Apellániz et al. 2015; Simón-Díaz et al. 2015), of which the most extraordinary case is η Car, a high-eccentricity ($e = 0.9$) binary in a 5.54-year orbit (Damineli 1996; Damineli et al. 2000), where the periastron passages have led to violent events which have changed the fate of the system in short time-scales (Smith 2011).

HD 93 129 A, the central system of the compact massive young cluster Trumpler 14 in the Carina Nebula, has long been recognized as one of the hottest and most massive stellar systems in the Galaxy (Walborn 1971). It is the prototype of the earliest O spectral subtype of supergiants (O2 If*) and its only example known in the Galaxy (Walborn et al. 2002; Sota et al. 2014). Nelan et al. (2004) resolved it with the Fine Guidance Sensor (FGS) on board the *Hubble Space Telescope* (*HST*) as an astrometric binary (Aa,Ab components). Maíz Apellániz et al. (2008) detected a relative astrometric motion between the two components, with the separation in the plane of the sky between them decreasing in a nearly inward direction, and suggested that the system followed a highly eccentric and/or inclined orbit. The speed of the inward motion increased in subsequent years, lending credence to the high-eccentricity option (Sana et al. 2014; Benaglía et al. 2015). The previously published data show a decrease from a distance of 66 mas in 1996 to 28 mas in 2012 (2.4 mas a^{-1} on average).

2 METHODS

2.1 Astrometric data

We measured the relative astrometric orbit of HD 93 129 Aa,Ab using positions from the following.

(i) One previously published epoch from FGS/*HST* (Maíz Apellániz et al. 2008; Benaglía et al. 2015).

(ii) Two epochs from the High Resolution Camera (HRC) of the Advanced Camera for Surveys (ACS) on board *HST* (Maíz Apellániz et al. 2008).

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Table 1. Relative astrometry for the HD 93 129 Aa,Ab system. The first three columns show the Julian Date of the observation, the separation, and the position angle (measured counterclockwise from North). The next three columns give the semimajor and semiminor axes plus the position angle of the uncertainty ellipses. The last column gives the instrument used.

JD (d)	Separation (mas)	PA (deg)	$\sigma_{\rm max}$ (mas)	$\sigma_{\rm min}$ (mas)	PA$_\sigma$ (deg)	Instrument
245 0214.42	66.00	11.50	13.82	2.00	102	FGS/*HST*
245 3224.09	53.02	14.83	1.30	1.16	105	HRC/*HST*
245 3950.06	45.11	16.75	1.42	1.04	17	HRC/*HST*
245 6087.98	28.35	9.57	1.42	0.73	149	PIONIER/VLTI
245 6995.36	17.49	5.98	1.50	0.59	132	PIONIER/VLTI
245 7392.23	11.61	2.66	0.65	0.29	130	PIONIER/VLTI
245 7481.24	10.22	0.87	0.95	0.24	51	PIONIER/VLTI

(iii) Five epochs from the Precision Integrated-Optics Near-infrared Imaging ExpeRiment (PIONIER) four-beam combiner at the Very Large Telescope and Interferometer (VLTI) at the European Southern Observatory (ESO; Le Bouquin et al. 2011; Sana et al. 2014). Of those, only the first one had been published before.

The measured values are listed in Table 1.

The HRC data (from *HST* GO programs 10205, 10602, and 10898) were processed using a crowded-field photometry package created by the lead author, which works on the geometrically distorted (not on the drizzled) exposures (Anderson & King 2004). Three different HRC filters (*F*330*W*, *F*435*W*, and *F*850*LP*) were used. The excellent quality of the double point spread function (PSF) fit can be appreciated in Fig. 1. The existence of seven unsaturated bright stars belonging to Trumpler 14 in the HRC field allowed us to measure not only relative motions (in the plane of the sky) but also absolute motions by assuming that the rest of the stars remained stationary during the two-year span between the two HRC epochs (2004.589 and 2006.586). The *F*435*W* and *F*850*LP* filters were used for the absolute proper motion measurement.

The new VLTI/PIONIER observations were obtained with the auxiliary telescopes in configuration A0-G1-J2-J3, which provides a maximum baseline of 132 m, corresponding to a spatial resolution element in the *H* band of 2.5 mas. The observations were processed following the procedure described in Sana et al. (2014) and references therein. The HD 93 129 Aa,Ab binary was clearly resolved at each epoch. A binary model with three parameters (separation, position angle, and brightness ratio) was fitted to the visibilities and closure phases in order to obtain sub-milliarcsec precision relative astrometry of the two components of the system.

2.2 Spectroscopic data

We observed HD 93 129 Aa,Ab with the Space Telescope Imaging Spectrograph (STIS) on board *HST* using the G430M and G750M gratings in 2010.264 aligning the slit with the position angle of the system at that time, when the pair was separated by 36 mas, to obtain individually resolved spectra of the two components (Fig. 2). The separation between the stars was smaller than the spatial pixel size of the STIS CCD (50 mas). To overcome that, we (a) dithered the exposures spatially with a two-point pattern in order to decrease the effective pixel size to 25 mas and (b) we used the techniques developed for MULTISPEC (Maíz Apellániz 2005) to obtain spatially resolved spectra for both the Aa and Ab components.

We have obtained 42 optical spectra of HD 93 129 Aa,Ab between 2005 and 2016 using the Fiber-fed Extended Range Optical Spectrograph (FEROS) spectrograph attached at the Max Planck institute for Extraterrestrial physics/ESO 2.2-m telescope (La Silla Observatory, Chile) and the Échelle spectrograph attached to the du Pont 2.5 m (Las Campanas Observatory, Chile). The data were obtained within the framework of the OWN Survey (Barbá et al. 2010). The slit widths used in those observations (2 arcsec in FEROS, and 1 arcsec in Échelle) do not allow us to spatially resolve the Aa and Ab components. They provide nominal resolving powers of 48 000 and 45 000, respectively. The data were processed using the FEROS Data Reduction System implemented within ESO-MIDAS software, and the échelle package in IRAF. Additional processing such as rectification and telluric corrections were performed using IRAF. The final signal-to-noise ratio of the one-dimensional extracted spectra depends on the wavelength and the observing night, varying between 100 and 400. We have measured the radial velocity, equivalent width, and full width at half-maximum for a number of absorption and emission lines in the spectra in order to determine the behaviour of those parameters with time.

Ultraviolet and Visual Echelle Spectrograph (UVES)/VLT observations were obtained on the night of 2016 June 27 with the DIC2 436+760 and 346+820 setups, yielding a continuous wavelength coverage from 305 to 498 nm and from 570 to 945 nm. Two back-to-back exposures of 150 s were obtained in each setup. An entrance slit of 0.6 arcsec was used for both arms, yielding a nominal spectral resolving power of 60 000. The data were processed in the standard way using the ESO-CPL pipeline v5.7.0 under the REFLEX environment and calibration frames obtained within 12 h of the scientific observations. The extracted one-dimensional spectra were rectified by fitting a low-order polynomial through the continuum and show a signal-to-noise ratio per resolution element of about 400. To complement our time series, archival UVES observations of HD 93 129 Aa,Ab from 2013 April and 2015 April were further retrieved from the ESO archive data base and processed in a similar way.

3 RESULTS

3.1 Relative astrometric orbit

Since only a fraction of the relative astrometric orbit is available and only seven epochs have been obtained so far (Table 1), it was not possible to derive precise values for all seven independent parameters which need to be determined, which we chose to be (among the different possible combinations): (1) orbital period P, (2) periastron epoch T_0, (3) eccentricity e, (4) periastron distance d, (5) inclination i, (6) ascending node longitude Ω, and (7) the difference between the periastron argument and the ascending node longitude $\omega - \Omega$. A simple search for the maximum likelihood point (mode) under such circumstances is not sufficient, as the likelihood in the seven-dimensional parameter space is likely to have multiple peaks. For that reason, we conducted a full search over the plausible parameter ranges, we calculated the likelihood at $\sim 10^{11}$ grid points, and we selected the 2.6×10^8 points with the highest values. Results are shown in Table 2 and in Figs 3–5.

Two families of orbital solutions are observed.[1] The first one has clearly defined values of $T_0 \approx 2017.25$ a, $e \approx 0.991$, and $d \approx 0.45$ mas and more loosely constrained values of P between

[1] In turn, each family is divided into two subfamilies separated by 180° in Ω. This degeneracy is caused by the absence of radial velocity points in the astrometric orbit which would allow us to decide whether the secondary is moving towards us or away from us at a given point in the orbit.

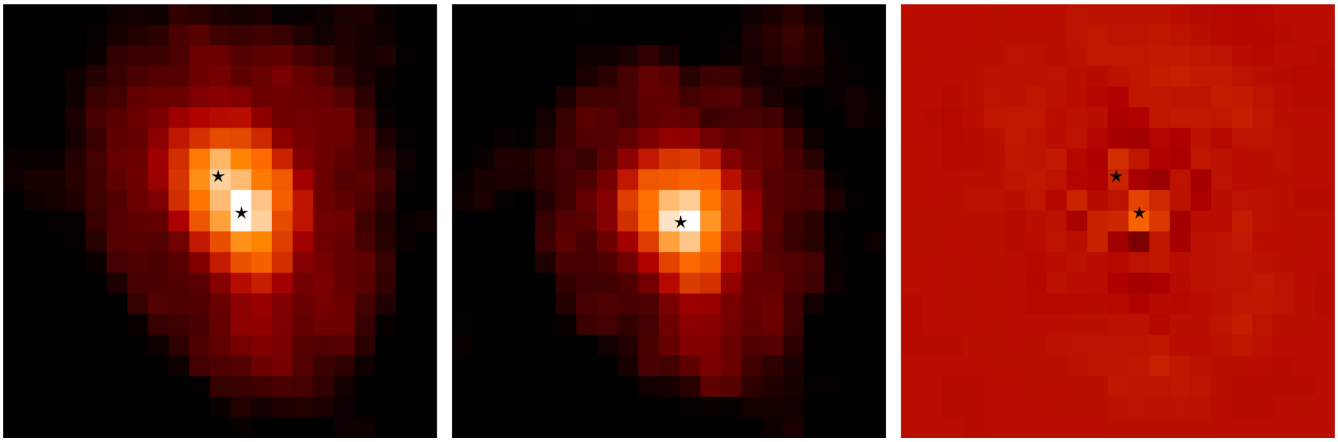

Figure 1. Left: imaging data, centre: point spread function (PSF), and right: fit residual (data with the two stars subtracted) for one of the *F435W* HRC 2004 exposures. In the left and centre panels, the intensity scale is logarithmic between 0.1 per cent and 100 per cent of the maximum, while in the right-hand panel the intensity scale is linear between −3 per cent and 3 per cent of the data maximum. The star symbols mark the position of the two components (Aa, centre, and Ab, upper left) in the two extreme panels and the PSF centre in the centre one. The field size is 0.53 arcsec×0.53 arcsec .

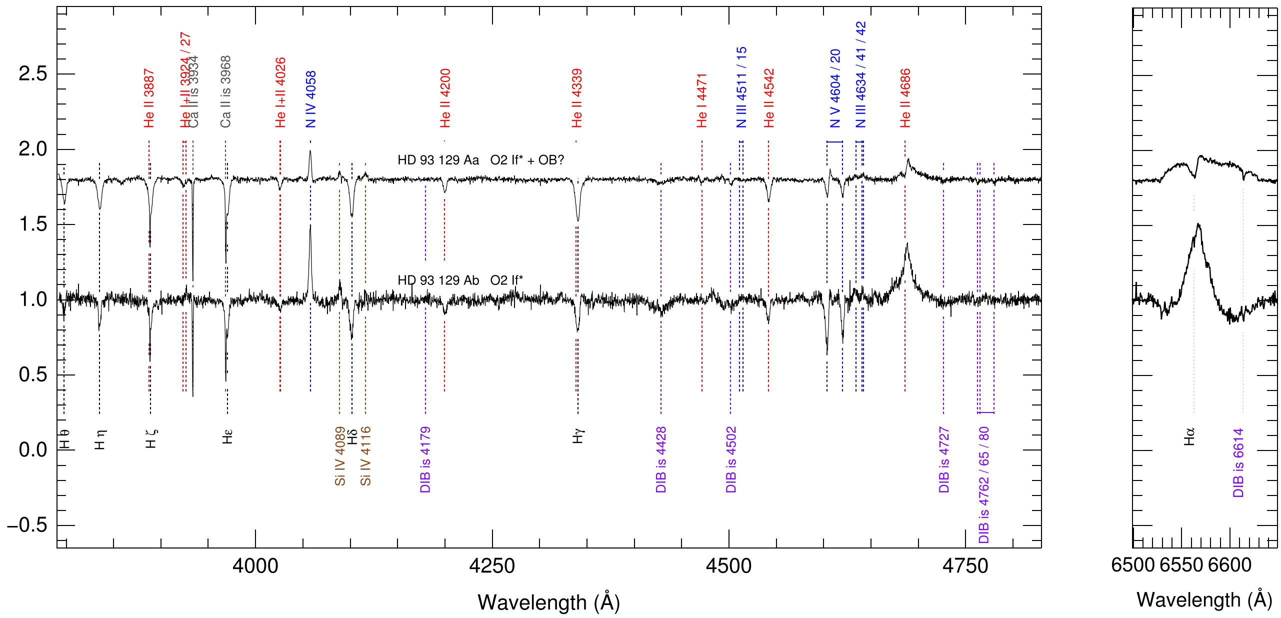

Figure 2. Spatially resolved rectified STIS spectra of HD 93 129 Aa and Ab: (left) blue-violet region and (right) Hα. The spectra have been displaced in the vertical direction for clarity. The HD 93 129 Ab spectrum is noisier than that of Aa due to the ≈1 magnitude difference between the two components (see also Fig. 1, note that the intensity scale in the left and centre panels there is logarithmic).

100 a and 250 a and of i between 150° and 180°. The second one is more dispersed in the parameter space, with P between 50 a and 120 a, T_0 between mid-2017 and mid-2018, e between 0.92 and 0.99, d between 0.5 and 4 mas, and i between 100° and 130°. In any case, all solutions are highly eccentric and with periastron passages in 2017/2018 within less than 14 au (6 mas). Further VLTI observations are needed to establish which of the two families is the right one. No periastron passage between two massive stars with such a high eccentricity has ever been observed.

3.2 Spectral classification

The spatially resolved STIS spectroscopy allowed us to obtain individual spectral classifications for the Aa and Ab components. Both stars have similar spectral types, with very weak or no He I 4471 absorption, strong He II 4542 and N V 4604+20 absorptions, He II 4686 in emission, and strong N IV 4058 emission (much larger that the weak N III 4634+41+42 emission). This makes both objects O2 If*, the earliest subtype of O supergiants (Walborn et al. 2002; Sota et al. 2011), and contrasts with previous assumptions that the secondary was of a later spectral type such as O3.5 (note that such claims were based on indirect evidence, not on observed spectra). Even so, there are some differences between the two components: (a) Hα and He II 4686 are in pure emission for Ab but have signs of an absorption component for Aa and (b) He I 4471 absorption is completely absent for Ab but is seen (very weak) in Aa (the weak absorption feature is also observed in the spatially unresolved ground-based spectra). Those differences could be explained if Aa itself is a tight binary (Aa1,Aa2) composed of an O2 supergiant (Aa1) and a later-type companion (Aa2). See below for further evidence regarding this hypothesis.

Table 2. Relative two-body orbital parameters for HD 93 129 Aa,Ab based on the astrometric data. The first block lists the fitted parameters and the second block the derived ones. The very large uncertainties for Ω and ω arise from the existence of two subfamilies of solutions separated by 180° (i.e. we do not know if the Ab component is moving towards us or away from us at a given point).

Quantity	Units	Value
P	a	121^{+60}_{-39}
T_0	a	$2017.60^{+0.38}_{-0.32}$
e		$0.967^{+0.023}_{-0.026}$
d	mas	$2.7^{+2.2}_{-1.7}$
i	deg	117^{+28}_{-7}
Ω	deg	192^{+15}_{-173}
$\omega - \Omega$	deg	-24^{+12}_{-12}
$a_{\mathrm{Aa,\,Ab}}$	mas	50^{+12}_{-7}
ω	deg	177^{+153}_{-143}
$m_{\mathrm{Aa,\,Ab}}$	$\mathrm{M}_{\odot}$	108^{+52}_{-15}

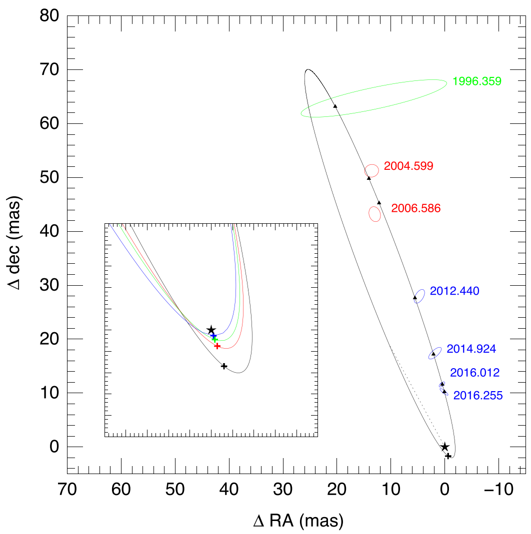

Figure 3. Best (mode) relative two-body orbit projected on the plane of the sky for HD 93 129 Aa,Ab based on the astrometric data. The star shows the orbital centre, the ellipses the data (green = FGS, red = HRC, blue = PIONIER), the text the observation epochs (in a), the triangles the predicted positions, the cross the periastron location, and the dotted line the line of nodes. The inset shows the inner 10 mas×10 mas with four different orbits with $\chi^2_{\mathrm{red}} < 1$. The mode orbit is drawn in black and is the one with the latest periastron epoch (2018.14) and distance (2.085 mas) and the lowest eccentricity (0.952). The other three orbits are drawn in red, green, and blue and follow decreasing sequences in periastron epoch (2017.66, 2017.48, and 2017.30) and distance (0.975, 0.615, and 0.375 mas) and increasing sequences in eccentricity (0.980, 0.988, and 0.993). Crosses mark the periastron locations. 1 mas = 2.35 au at the distance to the Carina Nebula (Smith 2006).

3.3 Mass ratio

The absolute proper motion derived from the HRC/ACS data yield a mass ratio between the Ab and Aa components of 0.49 ± 0.22. This is anomalously small for two objects of the same spectral type but could be at least partially explained if Aa is indeed a tight binary, as suggested above. The relative astrometric orbit also yields an estimate for the total mass for the system (Table 2). While uncertainties are still large, given that we only have a partial orbit and that two families of solutions are allowed, we obtain values firmly above 60 $\mathrm{M}_{\odot}$ for Aa and above 30 $\mathrm{M}_{\odot}$ for Ab (and possibly much higher), making HD 93 129 Aa,Ab the most massive astrometric binary (or triple system) known (Sana et al. 2013; Sánchez-Bermúdez et al. 2013).

3.4 The spectroscopic multiplicity of the HD 93 129 A system

The spatially resolved STIS spectra also allowed us to measure the line-of-sight velocity difference Δv_r between Ab and Aa (positive for Ab moving away from us) in 2010.264. The N IV 4058 emission line yielded $-0.3 \pm 2.8\,\mathrm{km\,s^{-1}}$ (note that this line depends on the wind properties) and the N V 4620 absorption line yielded $+6.0 \pm 5.3\,\mathrm{km\,s^{-1}}$. Both results are compatible and indicate that in 2010.264 there was little motion along the line of sight, which is consistent with the expected velocities from the astrometric results (Fig. 5), but provides no strong additional constraint on the relative orbit (e.g. in breaking the degeneracy between the two Ω subfamilies).

In the ground-based spectroscopic data (FEROS, Échelle, and UVES), Aa and Ab are unresolved (HD 93 129 B, a more distant bright star is not included). We observe time-dependent velocity differences up to $15\,\mathrm{km\,s^{-1}}$ in the strong N V 4620 absorption line and up to $50\,\mathrm{km\,s^{-1}}$ in the weak He I 5876 absorption line (the former would originate in Aa1, the primary of the Aa1,Aa2 system, and in Ab while the latter would originate in Aa2, the secondary of the Aa1,Aa2 system), as well as profile variations in the He II 4686 emission line. Those changes occur in time-scales of a few days and they are not secular, as would be expected from the evolution of the Aa,Ab orbit (Fig. 5), so they represent further evidence that Aa is a tight binary. We are analysing the modulation of these radial velocity variations. Some possible periods have been detected but a definitive orbit cannot be derived at this time. We plan to obtain further epochs to achieve that and we will report on the results as soon as we obtain them, given the proximity of the Aa,Ab periastron passage.

4 ANALYSIS

4.1 HD 93 129 A as a binary system

Former radio observations have revealed that the stellar winds of components Aa and Ab collide in-between the two stars. In this so-called wind-collision region (WCR), electrons are accelerated at the shock interfaces up to relativistic energies. As a result, the WCR produces intense non-thermal (synchrotron) radio emission (De Becker 2007; De Becker & Raucq 2013). The last radio observations, obtained in 2009 when the distance between the two stars was about two orders of magnitude larger than the value at periastron, showed that the flux was increasing with time (Benaglía et al. 2015, whose wind parameters we use here). However, given the extremely close encounter that we predict, the WCR will be pushed deep into the radio sphere of the stars and the non-thermal radio emission from the WCR will now be entirely absorbed by the stellar winds, except maybe at the higher frequencies (>20 GHz).

While the periastron passage of HD 93 129 A will be radio-quiet, the situation will be very different in the X-ray (and possibly γ-ray) domain. If the distance at periastron is indeed ≈0.45 mas, as predicted by our first family of orbital solutions, the non-thermal hard X-ray emission produced by the wind collision (mostly through

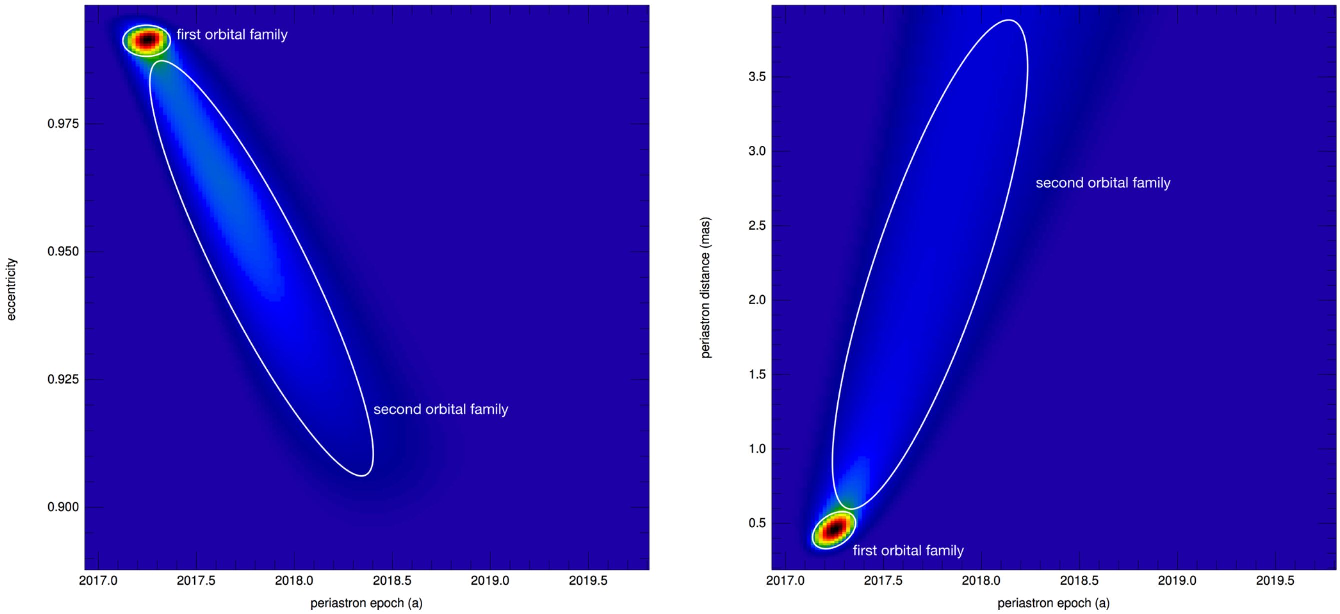

Figure 4. Likelihood distribution for the relative astrometric two-body orbit collapsed into the T_0-e (left) and T_0-d (right) planes. The regions with a large likelihood have been grouped into two orbital families (see text) and ellipses have been drawn to guide the eye. Note that each of the two families has relatively complex shapes in seven-dimensional space (i.e. they cannot be simply described by seven-dimensional ellipsoids). The integrated likelihood of the two families is similar, as the highest peak values (as projected in these planes) of the first one are compensated by the larger volume occupied by the second one.

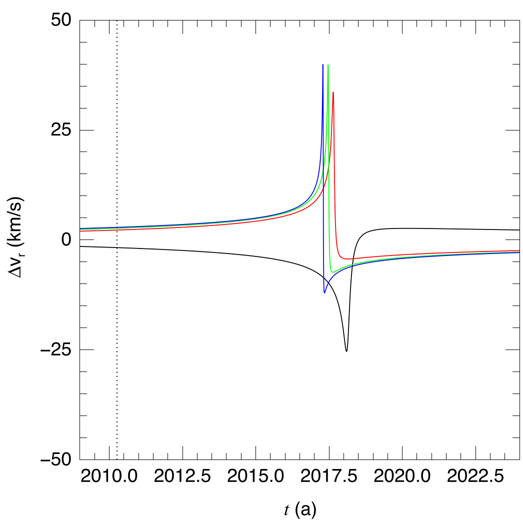

Figure 5. Radial velocity predictions for the four relative astrometric two-body orbits shown in the inset of Fig. 3. The dotted vertical line marks the epoch of the STIS observation. Note that currently Ω is undefined by $\pm 180°$, which causes the existence of solutions where Ab will be moving away from us near periastron and solutions where Ab will be moving towards us at that time. We show three of the former and one of the latter.

inverse Compton scattering) should increase by two order of magnitudes compared to the epoch of the last X-ray measurements (Gagné et al. 2011). This is about 10 times more intense than the most optimistic scenario so far (del Palacio et al. 2016). Applying a $1/D$ scaling to the existing models (del Palacio et al. 2016) to account for the new periastron distance (which we can do because the WCR cooling properties remain in the adiabatic regime, even at periastron), we find that the non-thermal emission will dominate the X-ray flux of the system above a couple of keV, possibly leading to one of the more obvious high-energy detections of non-thermal processes in stars. A characterization of the evolution of WCR non-thermal radio + X-ray properties and their relative comparison will allow astronomers to obtain unprecedented constraints on the particle acceleration mechanism, with immediate implications to understand the production mechanism at the origin of cosmic rays, which are thought to be accelerated through similarly strong shocks in supernovae remnants.

How does HD 93 129 Aa,Ab compare to η Car? The masses are not too different, especially if the low-mass models for η Car are considered (Clementel et al. 2015; Kashi & Soker 2016 and references therein), but the primary star in η Car is more evolved and the interaction with the secondary appears to have become significant for their evolution just after the primary became an evolved hypergiant, thus allowing the companion to graze the hydrostatic core radius of the primary. That is still far in the future for HD 93 129 Aa,Ab in terms of number of orbits (thousands or tens of thousands) so, in the absence of perturbations (see below), we should not expect mass ejections during the next periastron like those experienced by η Car. One important difference exists between η Car and HD 93 129 Aa,Ab. η Car is located in Trumpler 16, a loose cluster whose full extent is not clear, and has no rival there in terms of stellar mass. On the other hand, HD 93 129 Aa,Ab is at the centre of Trumpler 14, a compact, dense cluster with two other very massive stars in the core itself, HD 93 129 B and HD 93 128 (Sota et al. 2014). Therefore, the Aa,Ab highly eccentric orbit should be easy to perturb and the system may experience a very different demise (becoming unbound or having a too-close approach at periastron). In any case, a close monitoring of the orbit in the incoming years should shed some light on the issue.

Most known examples of very massive stars are of spectral type WNLh/ha or O Iafpe (also known as 'late Of/WN' or 'cool slash', Sota et al. 2014), see e.g. Moffat et al. (2004); Crowther et al. (2010); Crowther & Walborn (2011), and Maíz Apellániz et al. (2015) for a recent listing. However, given the small sample known, it is not clear if all of the stars with masses $\gtrsim$ 100 $M_\odot$ have the WR features that prompted Phil Massey to call them 'Of stars on steroids' (Moffat & Puls 2003). Our determination of the masses of the HD 93 129 A stars currently has relatively large uncertainties, but our current results do not exclude values around 100 $M_{\odot}$ for the most massive component. A better determination of the masses could make this system a crucial case to decide the issue, as HD 93 129 A has the advantage over other examples of being an astrometric binary, thus exempt from the inclination problem that affects the determination of masses in non-eclipsing spectroscopic binaries. But why should two stars of the same mass have different spectral types? A traditional stellar-evolution answer would be an age difference (e.g. a $\sim$100 $M_{\odot}$ star could be born as an O star and evolve into WNLh/ha around an age of $\sim$1 Ma) but other possibilities (binarity, rotation, mergers, metallicity, etc.) exist.

4.2 HD 93 129 A as a triple system

The analysis above is based on HD 93 129 A having only two components. If HD 93 129 Aa is a tight binary (as different pieces of evidence indicate), this periastron passage should be treated as a three-body problem and that opens up new possibilities.

The first possibility is that one of the three stars is ejected at high speed and becomes a runaway star. That scenario for the production of a runaway star at the core of a compact cluster with massive stars was proposed almost half a century ago (Poveda, Ruiz & Allen 1967) but has never been observed in action (and probably never thought that it would take just decades instead of millennia to observe it for the first time). It is fitting that, if it indeed happens in this system, such a first occurrence takes place in Trumpler 14, which is the closest example of a compact massive young cluster with very massive stars.

A second possibility is a collision between two of the three stars if the periastron of the Aa,Ab orbit takes place at a distance comparable to the semimajor axis of the tight binary. Such an event between two massive stars has never been directly observed though eruptions in lower mass systems such as V838 Mon (Tylenda & Soker 2006) and V1309 Sco (Tylenda et al. 2011) have been proposed (after the fact) as the result of stellar collisions (but possibly due to slow, tidally induced inspiralling, not as the result of a fast, three-body interaction). Therefore, if the outcome of the periastron passage of the Aa,Ab orbit is the collision between either pair of the three stars (Aa1, Aa2, and Ab) it would be the first time that (i) a stellar collision is followed through the process knowing the possible outcome beforehand and (ii) the event involves massive stars, one of them very massive. As it was the case with the first possibility, it would be fitting that such an event is first observed in the core of Trumpler 14, since the core of massive young stellar clusters has been proposed as the most likely location for them (see Portegies Zwart et al. 1999 for an optimistic version of the importance of stellar collisions and Moeckel & Clarke 2011 for a more pessimistic one).

A third possibility is that the periastron passage is relatively uneventful and Ab leaves it in a slightly perturbed orbit, returning decades or centuries later[2] (the current uncertainty on P is large, see Table 2). Even if that is the case, the system is likely to be unstable in the long-term for three reasons: (i) the current Aa,Ab eccentricity is very large, so even a small perturbation can cause a large effect; (ii) as already mentioned, there are two nearby very massive stars, HD 93 129 B and HD 93 128 (Sota et al. 2014), and several other massive stars that may also perturb the already eccentric orbit; and (iii) the Lidov–Kozai effect (Kozai 1962) can perturb the orbit of the inner pair and cause a collision between those two stars. Indeed, it has been proposed that η Car was also a triple system and that the Lidov–Kozai effect caused two of the stars to collide and produce the mid-nineteenth eruption (Portegies Zwart & van den Heuvel 2016).

Which one of those possibilities is more likely? We do not have an answer yet but the most important parameter that needs to be determined is the ratio between the Aa,Ab periastron distance and the Aa1,Aa2 semimajor axis. If that value is $\sim$1 or less (i.e. if the orbits cross or nearly so), then the first two possibilities can take place with relatively high probability. If, on the other hand, the value is $\gtrsim$3, we would be looking into the third scenario. The answer should come from two sources: (i) further interferometric observations before the periastron passage to measure its distance more accurately and (ii) a determination of the Aa1,Aa2 orbit though a high-S/N multi-epoch spectroscopic campaign. We note the urgency of these observations: the chance to observe such a spectacular interaction between massive stars may not be repeated in a long time. In that respect we have already obtained time for further PIONIER and spectroscopic observations in the incoming months.

What about the previous orbital evolution? The system may have been born in a similar configuration and Ab would have orbited around Aa thousands or tens of thousands of times with little variation from one orbit to another, along the lines of the third possibility above but going backwards in time. However, the three considerations listed above (very high eccentricity, perturbations by other Trumpler 14 stars, and the Lidov–Kozai effect) make this unlikely: our impression is that the system is more likely to have been born in a different configuration though a more definitive answer would require numerical simulations. This means that the number of previous orbits is currently unknown. Going to the other extreme, if the $e \approx 0.991$, family of solutions turns out to be the correct one; Ab could have been recently captured by Aa and we could be witnessing not only one of the last but also one of the first periastron passages of the system.

5 CONCLUSIONS

The eccentric HD 93 129 Aa,Ab system will pass through a close periastron in 2017/2018, providing a unique opportunity to study the interaction between two powerful stellar winds. The system is already an intense X-ray emitter but in a scenario with $d < 1$ mas, as suggested by our first family of orbital solutions, the constraints we have placed on the relative orbit between the two components will produce a strong outburst at least an order of magnitude more intense than previous estimates. The evolution of the WCR properties should produce new insights into the particle acceleration mechanisms.

We have also found three pieces of evidence that the Aa component is itself a binary system: (i) its spatially resolved spectrum shows features that are inconsistent with those of a single object, (ii) the mass ratio derived from the absolute proper motions indicates that Aa is significantly more massive than Ab while the spectral classification points towards them being very similar objects, and (iii) the spectral lines in the integrated spectrum show short-term velocity variations inconsistent with the long-term variations expected from the Aa,Ab orbit. Therefore, we expect the 2017/2018

[2] A combination of these possibilities could also take place. For example, the first Aa,Ab periastron passage could produce a serious orbital perturbation that would lead to one of the first two possibilities in a subsequent periastron passage.

periastron to be a three-body encounter with different possible outcomes. It could be uneventful in the short term if Ab passes at several times the Aa1,Aa2 distance, but it could also lead to a runaway ejection or a stellar collision if the periastron distance is shorter. In any event, such an eccentric three-body system located at the centre of a massive young cluster should be dynamically unstable in the long term and it is unlikely that it will remain unperturbed until the point where stellar evolution changes the characteristics of the stars significantly.

The comparison with η Car is undoubtedly interesting, especially since η Car may have been a triple system itself and its current status may have had more to do with stellar dynamics than with stellar evolution. There are now two very massive multiple systems in the Carina Nebula with orbits so eccentric as to make their destinies depart strongly from what we would expect for isolated stars or for nearly circular binary systems. How common are such systems? How influential are they for the evolution of very massive stars in general? What fraction of Luminous Blue Variable eruptions are caused by three-body interactions? As usual in this field, better statistics are needed but the sample is likely to remain small in the short term.

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